Contact Stress Distribution Microsensor Array and Optical Force Probe

For more information contact **Jack Kotovsky**
(925) 424-3298, kotovsky1@llnl.gov

Many applications require the knowledge of interface stresses for system analyses and control. Examples include the optimization of hip and knee surgery, robotic tactile sensing, internal combustion engine gasket work, and stockpile stewardship demands. An instrument that measures interface stresses must be thin so as not to disturb the stress it measures, and be able to conform to the surfaces it is sandwiched between. These constraints pose numerous technical challenges, to which this work is applied.

Project Goals

The goal of this project is to improve the measurement of interface stresses. To accomplish this goal, this project demonstrates novel instrumentation. The work is divided into two different technologies: electronic and optical measurement systems.

For the electronic system, this year's work seeks to demonstrate all facets of a Contact Stress Sensing Array (CSSA) system. This system is comprised of MEMS stress sensors, an integrated process to interconnect these elements in a 2-D flexible array (see Figs. 1 and 2), control electronics, signal conditioning, and PC-based data acquisition system.

For the optical system, the goal is to demonstrate a novel Optical Force Probe (OFP) and a Modular Optical Assembly necessary for the probe's function.

Relevance to LLNL Mission

This work demonstrates tools that provide support to LLNL weapons programs and stockpile stewardship, and to many other applications within and beyond LLNL. The effort produces new capabilities

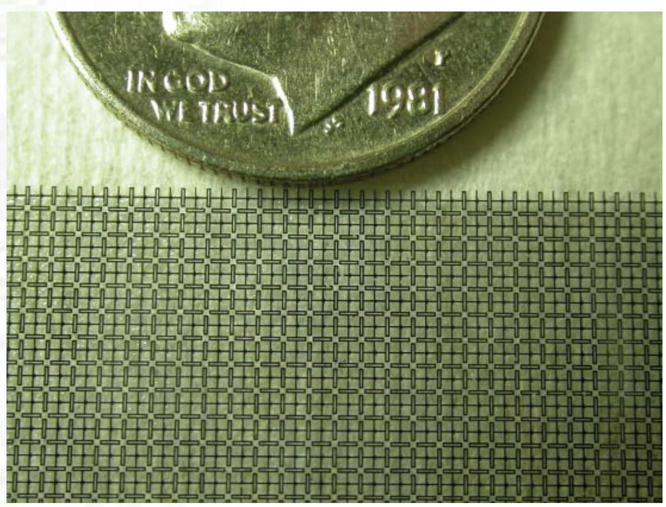

Figure 1. Magnified view of silicon contact stress-sensing array. This prototype demonstrates novel etching and wafer handling of a 1500-sensor array of 60-µm thickness. Approximately 300 sensors with interconnects are shown next to a dime.

in plasma etching, wet etching of silicon, metallization techniques, nonconventional photolithography, sensors, optical fiber handling, optical fiber alignment, and integrated micro-optomechanical assembly. The work paves the way for LLNL to field novel instruments in stockpile stewardship, and acts as a forcing function for expanded MEMS production capability in the DOE complex.

FY2004 Accomplishments and Results

Key technical milestones have been achieved this year, including novel techniques in photolithography, metallization, wafer handling, and silicon plasma etching. Large, freestanding, integrated silicon arrays can be produced for the first time. The arrays contain silicon contact stress sensors of 60 μm total thickness, with an interconnect scheme allowing complex curvature conformity. This demands array flexibility and extensibility within its plane to achieve two bending radii. Process advances allow the interconnects to be processed independently from the sensing elements, releasing the overall process flow from difficult constraints. Our tools of process monitoring and extensive characterization of the sensing element have improved the sensitivity, accuracy, and linearity of the devices (Fig. 3). The control electronics and signal conditioning have also been realized.

The Modular Optical Assembly has been produced and characterized. Its performance exceeds expectations and provides a robust critical alignment necessary for the OFP's function. The silicon portion of the OFP has also been achieved following advances in plasma etching to produce small, three-dimensionally sculpted devices. The complete OFP is now functioning for the first time.

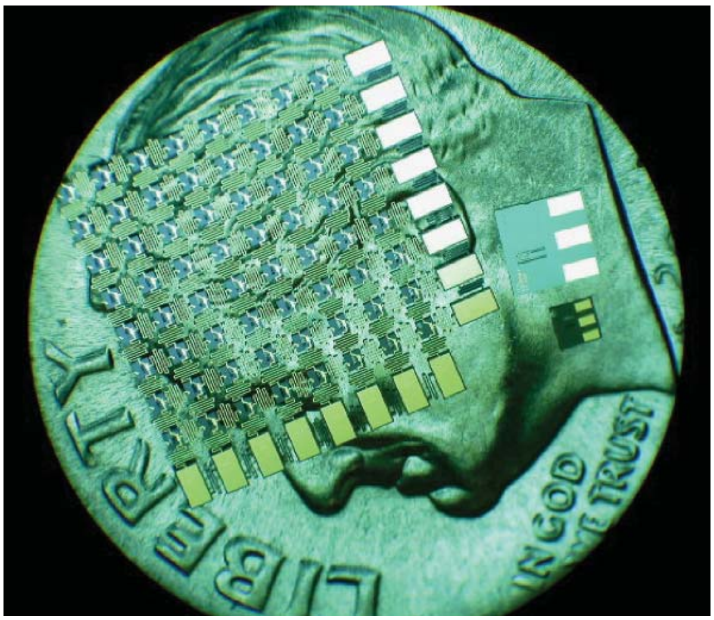

Figure 2. Single and arrayed contact stress sensors shown on a dime. These complete devices are built to measure 0 to 500 psi at a contact interface, and are 50 µm in thickness.

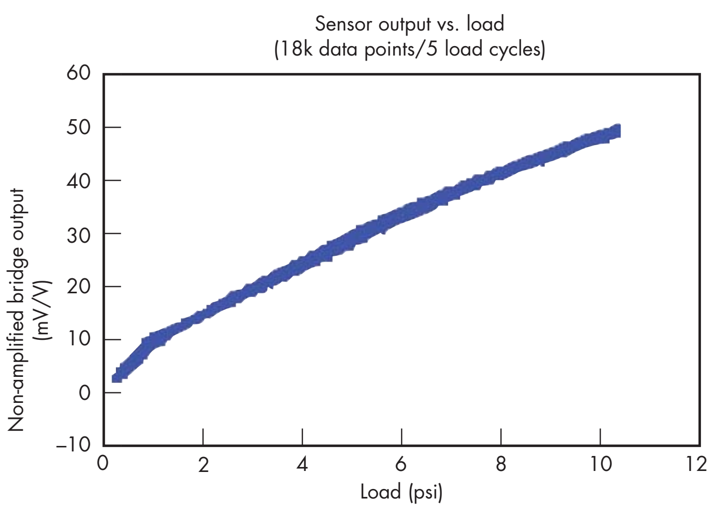

Figure 3. Example output of contact stress sensor.

FY2005 Proposed Work

Our work on contact stress-sensing arrays will be continued by integrating its components into a complete system. A hybridized silicon rubber package will be produced that accommodates the in-plane extensibility of the array. Once complete, the packaged array, control electronics, and acquisition system will be characterized under a variety of mechanical and thermal loads, and will be improved upon to achieve performance requirements. The OFP will be characterized and its fabrication optimized to provide desired performance requirements. The sensor-fiber assembly will be packaged with necessary strain relief to yield a fieldable instrument. The Modular Optical Assembly will be applied to other optical sensors.